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Approach for standardization of off-grid electrification projects

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ABSTRACT

Past experiences show that a large number of off-grid electrification projects fail because focus is generally given in technical installation without paying sufficient attention to the long-term sustainability of the projects. In such projects, several important steps, which need to be followed, are not covered. Moreover, there is no standardized approach, which could be followed while formulating the off-grid electrification projects. Therefore, there is a need for developing and benchmarking the systematic approaches, which could be followed for project planning and formulation. In this paper a modest attempt has been made to develop a decision making tool which involves approaches that are to be followed for entire planning and formulation of off-grid electrification project. The standardization of processes is expected to help in accelerating the implementation of off-grid electrification projects in an effective manner while fostering to achieve the national electrification targets in a stipulated timeframe.

Contents

1. Introduction

Electricity is one of the critical inputs for overall development of a country and is one of the main infrastructure requirements for agricultural, industrial and socio-economic development and also for employment generation especially in rural and remote areas. Though electricity forms on an average only about 10–12% of the total energy supply in the rural areas in most of the developing countries, yet electrification is virtually synonymous with modernization of the rural energy sector. This is because of the convenience and versatility of electricity in meeting the varied demands of rural population when compared to other forms of energy. Serving both as an infrastructure and input, the positive contribution of electricity to the Human Development Index is strongest for the first

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kilowatt-hour reflecting that the poorest are most likely to benefit from even minimal electricity inputs [1]. Rural electrification is also one of the key drivers in achieving Millennium Development Goals (MDGs) as it facilitates economic and socio-cultural development of the target population. Rural electrification is a declared objective of the central and state governments in India and has been accorded high degree of priority [2].

The problems of high transmission and distribution (T&D) losses; frequent disruption in supply of grid power, practical difficulties and financial un-viability of extending grid to remote and inaccessible areas, etc. are plaguing the rural electrification program in India. Off-grid electrification have proved to be the viable solution for providing electricity in remote areas such as islands, hilly regions and similar remote areas, where grid extension is economically not feasible. However, off-grid electrification using diesel-generating sets which have been tried in many remote areas are neither economical nor environmentally benign. The cost of generation from the diesel generating units installed in the remote areas is also high because of the high cost of transportation of fuel. The generation cost in remote revenue circles (such as Chayangtajo, Bameng, Tali, Sarli, etc.) in Arunachal Pradesh state in India ranges from Rs 8/- to as high as Rs 25/- per kWh depending upon the distance of the generating station from the nearest fuel depot [3]. On the other hand, the large number of remote areas in the country that have been electrified with renewable energy technologies have made a visible impact in the quality of life of the people inhabiting in these areas [4]. It is revealed that although several innovative off-grid electrification projects have been implemented world over, a majority remains at the pilot demonstration stage and yet to be fully institutionalised. Experience shows that when designing an electrification project, particularly a donor-driven project, it is very often the capital costs of the project (e.g. diesel generators, solar panels, turbines, etc.) that are taken into account without worrying too much about the services that need to precede or follow the installation of this equipment [5].

Past experiences show that a large number of off-grid electrification projects fail because focus is generally on technical installation without paying sufficient attention to the long-term sustainability. An assessment of the village electrification schemes funded by North Eastern Council, Govt of India indicates that 65% of the solar home systems, 60% of the power plants and 49% of the solar lanterns evaluated during the study are functional [6]. A major conclusion from the study revealed that lack of availability of adequate maintenance facilities was the main reason for non-functional status of most of the devices.

It can be said that Distributed Generation/off-grid electrification is yet to be tried on a large scale in rural electrification projects. There are still many barriers—technical, financial, regulatory, and institutional. Thus a clear and well-established framework is required to design, implement, and mainstream such schemes [7].

This necessitates the need for developing and benchmarking the systematic approaches, which could be followed for project planning and formulation. In this context, a modest attempt has been made to develop a decision making tool which involves approaches that are to be followed for entire planning and formulation of these projects. It is expected that such standardization of processes would help in accelerating the implementation of off-grid electrification projects in an effective manner while fostering to achieve the electrification targets of developing countries in a effective manner and within a stipulated timeframe.

2. Methodology

The components involved in project design and formulation of off-grid electrification such as selection of appropriate technology, adoption of appropriate financial model and formulation of suitable institutional set up, etc. are site specific and act differently (depending upon the type of resources available and socio-cultural dynamics), particularly for a geographically vast country like India. As one of the prime objectives is to standardize the process for project design and formulation, a review and analysis of pilot projects implemented in India by several organizations was done. Project related information was collected from different off-grid projects from across the country to capture the socio-cultural and agro climatic diversity primarily to incorporate the diversity of renewable energy resources availability (Fig. 1) [8].

Information was collected from projects located in different agro-climatic zones implemented by different agencies and capturing different renewable energy technologies [8]. The information on various processes adopted by organizations was collated from their Detailed Project Reports (DPRs). A stakeholder's consultation was also held to discuss the approaches adopted for off-grid electrification project planning and formulation [8]. In order to develop the financial framework for tariff determination, various existing revenue models were studied. Various components and parameters involved for tariff determination had been analyzed for development of a robust framework and financial tools.

3. Project design and formulation

The entire planning and formulation of off-grid projects can be categorized into 3 stages (Fig. 2):

Stage-I: Project development/planning and pre-installation.
Stage-II: Detailed designing, installation and commissioning.
Stage-III: Post-commissioning.

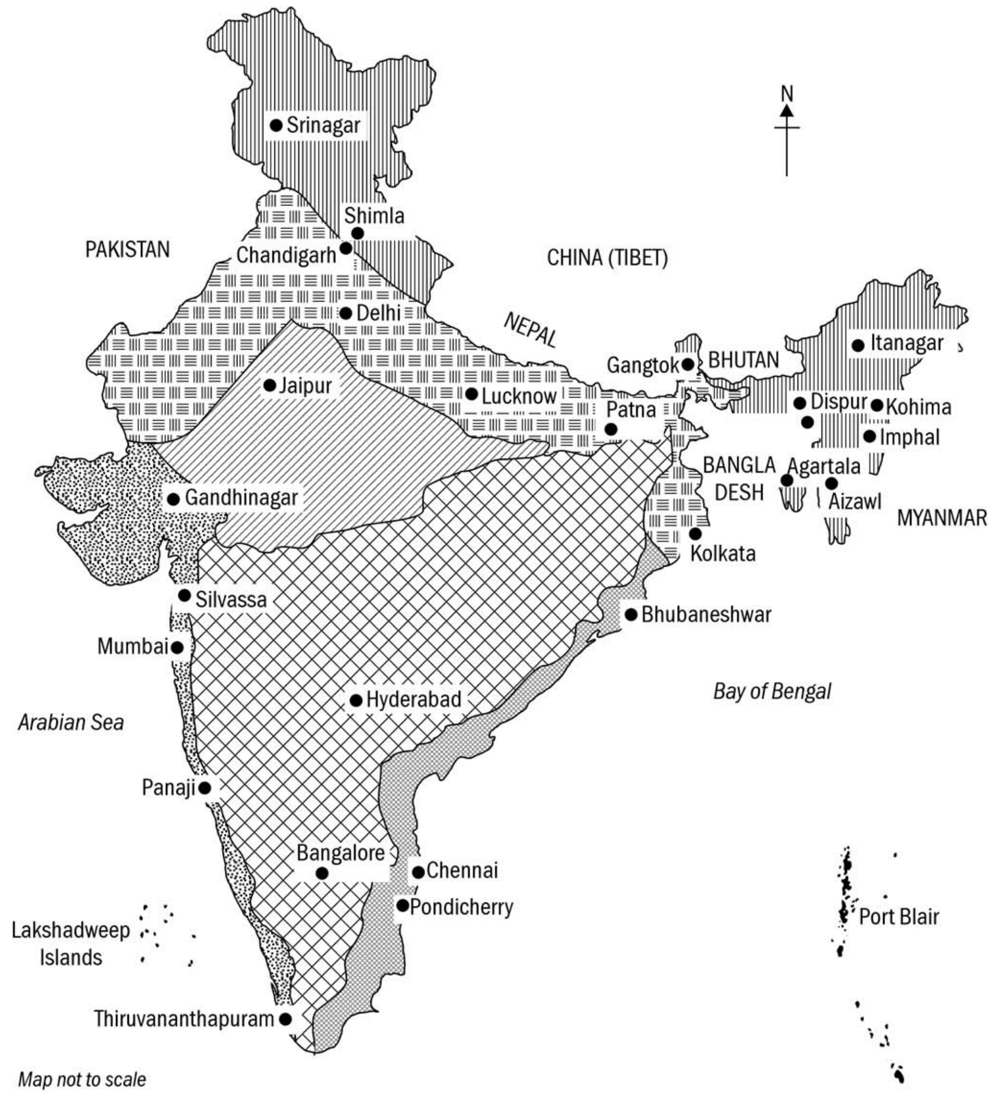
Each of the above mentioned stage involves execution of several steps, which are discussed in detail as below.

3.1. Project development/planning and pre-installation services

The project development/planning and pre-installation services stage essentially determines the potential sites for off-grid electrification project. To begin with, the geographical location of the region is first identified. Once the location is identified, following steps can be followed to find out whether grid extension is feasible or cost effective:

Step-I: Take a particular location or cluster of locations.
Step-II: Find out what is the terrain of that location (whether within forest, hilly region, island, plains).
Step-III: Make a preliminary assessment on the current/future demand of electricity (location of load centers) for that location/cluster of locations.
Step-IV: Make a preliminary assessment on the spread of the load centers.
Step-V: Find out what is the distance of existing grid from the load centers.
Step-VI: Using the information (from Step-II to Step-V), calculate the cost of electricity delivery through grid extension to that particular location.
Step-VII: Assess whether grid extension is cost effective or not.

If the grid extension is found to be unfeasible or not cost effective, then it is recommended to ascertain the possibility of setting-up of Distributed Generation (DG) based electrification project. For that, preliminary assessment on availability of sustainable supply of renewable energy sources has to be conducted. If the preliminary assessment ensures the availability



Pysio-graphic region	Agro-climatic region
The Himalayas	1. Western Himalayan region 2. Eastern Himalayan region
The Great plains	1.Gangetic plains region 2. Western dry region
The Central Highlands	1.Central Plateau and Highlands region
The Peninsular Plateau	1.Western Plateau and Hills region 2. Southern Plateau and Hills region 3. Eastern Plateau and Hills region
The West Coast Plains	
The East Coast Plains	
The Islands	

Fig. 1. Physio-graphic zone and different agro-climatic zones under each physio-graphic zone.

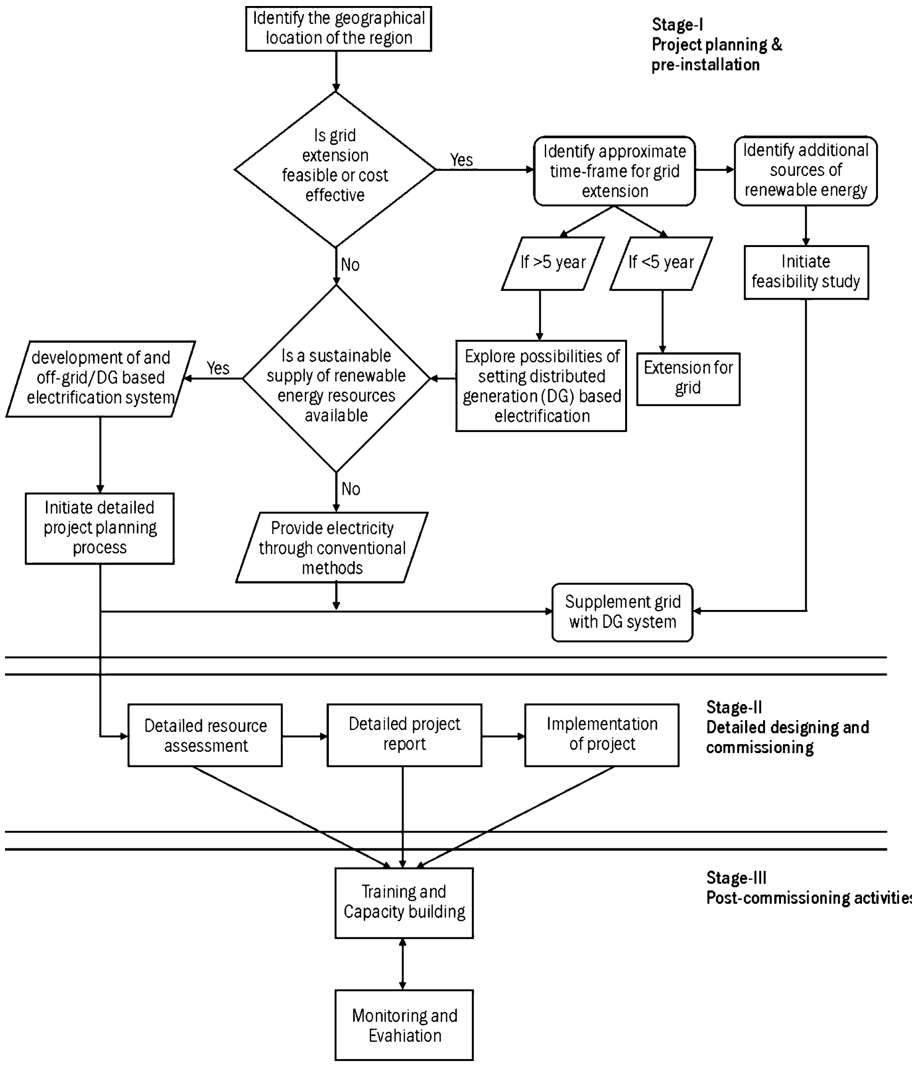


Fig. 2. Planning and formulation of off-grid electrification projects.

of sustainable supply of renewable energy resources then the site can be considered for off-grid/DG based electrification project and detailed project planning for the site can be conducted. Even if grid extension is found feasible or cost-effective, but the time frame for the grid extension process to reach the identified location from the utility is found to be more than threshold limit (say 5 years) depending upon policy and programme pertained to off-grid electrification of the particular state/country, it is recommended to explore the possibilities of setting-up of DG based electrification project. However, if neither grid extension is effective nor sustainable availability of renewable energy sources is ensured, the site can be chosen for using conventional source such as diesel gen-set for electrification.

3.2. Detailed designing and commissioning of the project

Detailed designing and commissioning of the project involves resource assessment, preparation of DPR followed by installation and commissioning of the project. Preparation of DPR includes all aspects of installation of the system such as technical, economic managerial and social.

3.2.1. Resource assessment

Resource assessment can be undertaken to determine if a sustainable supply/availability of renewable energy resource(s) is possible at the specified location. The renewable energy resources assessment can ideally follow a particular order of priority (priority on the basis of least-cost of electricity delivered). Fig. 3 describes the flow diagram for resource assessment.

Literature survey and research conducted by different agencies indicate that electricity generation and delivery through micro-hydro resources is the least cost option and thus availability of hydro resources is to be checked first.

The information can be collected through interaction and consultation with the local communities followed by actual measurements. As the discharge rate varies with season, month wise daily measurements at different time of the day for discharge rate of the water should be taken at least for 2 years. Other information such as use of water for irrigation and other purposes in the upstream also have to be collected.

Information needs to be collected for checking the availability of hydro resources are:

- Availability of suitable water source (canal, perennial stream, etc.).
- Duration of availability of water (in a year) in the water sources.
- Distance of water resources from the village (load centers).
- Head, discharge.
- Any other.

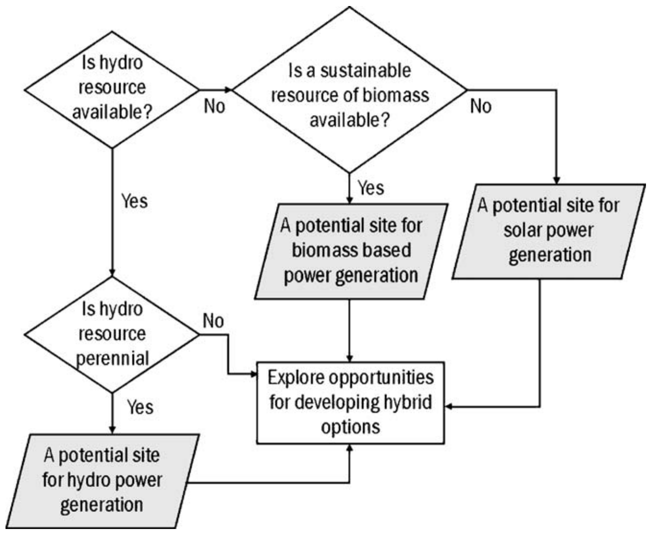


Fig. 3. Flow diagram for resource assessment.

If it is found that hydro resources is perennial, having desired discharge and head, then the site can be considered as a potential site for micro-hydro power generation. If the hydro resource is available but not perennial (due to seasonal variation), then the option of availability of other renewable energy sources can be explored, which should complement the hydro resources. If hydro resource is not available, the second choice could be biomass resource based technologies (such as biomass gasification, biogas and bio-oil/SVO) for power generation.

Information needs to be collected for checking the availability of biomass resources are:

- Availability of biomass resources.
- Type of biomass and its seasonal availability.
- Amount of extractable surplus biomass residue available (monthly/seasonally/annually).
- Associated issues of sustainable biomass harvest.
- Availability of consolidated land suitable for energy plantation.
- Any other source from where sustainable supply of biomass can be ensured.
- Willingness and readiness of other sources such as forest department to supply biomass.
- Availability of adequate source of water near to the potential site of biomass technology.

Availability of biogas resources can be assessed from:

- Present Livestock details.
- Productivity-Cattle dung available per day.
- Ease of collection-Whether Cattle are 'stall fed'.
- Distribution of cattle among community.
- Availability of adequate source of water near to the potential site of biogas technology.
- Whether the region is drought prone.

Availability of bio-fuel resources can be assessed from availability of surplus/waste/fallow land for bio oil/bio-crop plantation.

The above-mentioned information can be collected through semi-structured questionnaires, stakeholder's consultation, and actual measurements. If sustainable supply of biomass is ensured, the site can be considered as a potential site for biomass based power generation. If sustainable supply of biomass is not ensured, availability of wind as well as solar resources could be explored.

In general, small aero generators can be used in hybrid mode with other renewable energy systems such as solar photo voltaic power plants. Therefore to find out the wind potential, whether the location falls within windy region of the country is to be first checked. If the location comes under wind regimes, efforts can be made to collect the following information.

Information needs to be collected for checking the availability of wind resources are:

- Monthly average wind speed.
- Seasonal wind-speed.
- Annual average wind speed.
- Altitude.
- Time of day that tends to be windiest on average.

While conducting the resource assessment, availability of different resources should be explored (for hybrid option) even if the most cost effective resource is available. For example availability of biomass resources, solar resources, etc. are to be looked at for a site even if the site is found to be suitable for hydro resources. In other word, possibility of hybrid option at each location should be considered.

Information needs to be collected for checking the availability of solar resources are:

- Average Annual Insulation (kWh/sq m/day).
- Number of sunny, partially sunny and cloudy days every year.
- Habitation profile: Compact or distant.

3.2.2. Preparation of detailed project report

The DPR contains all necessary information that lead to the implementation of projects.[1] It contains the technical details about the system, economic viability of the system, institutional aspect that is to be incorporated for the smooth operation of the system. The technical details such as demand assessment, technology selection, sizing of the system as well as revenue model for tariff determination required for economic viability of the system is discussed in the following sections.

3.2.2.1. Demand assessment. Demand assessment can be categorized into domestic, commercial, community and agricultural demand.

Domestic demand assessment: Domestic demand typically consists of electricity for household lighting, for operating a fan and other household appliances (radio/television). As supply of electricity through DG based power projects are generally restricted to certain hours, the load profile also has to be collected. On the basis of the load assessment, an inference can be drawn on the current total domestic demand.

Community demand assessment: Community demand can be assessed based on community preference and requirement and on existing community infrastructure such as school, public health center, temple, youth club, etc.

Commercial demand assessment: A village electrification project providing only lighting leads to improved quality of life but may not lead to sustainability in the long run. It is desirable to develop other loads in addition to lighting for the betterment and economic stability of the village such that load development leads to continuous flow of revenues. From this perspective commercial load can be assessed. Commercial demand is the electrical load required for supporting certain village level commercial activities. Generally commercial load/demand in a village includes electricity for operating a flourmill, rice huller, etc. and may also include

[1] Resource assessment can be a part of Detailed Project Report, if not done separately.

electricity required for supporting certain small income generating activities. For assessing the commercial load requirements of the village, a primary survey can be conducted.

Agricultural demand assessment: Agricultural demand is the electrical load required for running primarily the agricultural pump set. However the agricultural load is seasonal and depends upon the agricultural practice of the villagers.

In addition to current demand assessment, load growth in each sector for next 5 and 10 years is to be considered. The load factor and diversity factor for each category of the load is also to be considered while finding the actual load that is to be met through the power system.

The approach used for assessing the demand could be a combination of primary and secondary data collected through questionnaire based household surveys, participatory rapid rural appraisal, and interviews with identified stakeholders. Surveys are conducted at two levels—(i) household level, and (ii) village level to collect the primary data.

Household level survey is used to understand the current energy consumption pattern to assess the electricity demand. It also gives an idea about the type and extent of energy requirement. Village level survey solicits demographic statistics, existing infrastructure, spread of the village, availability of resources, community and commercial demand, community participation, etc. The survey in addition to collecting information on the type of load requirements that exist at present should provide information on the possible requirements of electricity in the future.

Participatory approach is adopted in order to assess the prevailing energy situation in the villages. Issue based focused group discussions are organized to gauge the villagers' need for electricity, willingness to pay for better lighting and other electricity services issues related to sustainability of village electrification project in the long run. In addition to collection of information from villagers, several stakeholder consultations should be arranged to obtain a complete picture of the local requirements, situations and socio-cultural-economic conditions. Consultation with the following stakeholders can be arranged for this purpose.

- Forest Department.
- Block Development office.
- Revenue departments.
- Local renewable energy department.
- District Rural Development Agency.
- Agricultural department.
- Other prevailing institution such as Panchyat Raj Institution (PRI) in India.

The secondary level information could be gathered from available government records. Information on past trends of population growth, education levels of the local population, types and quantity of crops available and grown, pattern of land use, energy use pattern, etc. can be collected from such records.

3.2.2.2. Other assessment. It is often found in off-grid electrification projects that there are other parameters (besides technical), which are equally important and play a critical role in failure or success of a project. Therefore it is imperative to assess those parameters in the project formulation/DPR stage. Some of the assessment could be:

Willingness to pay: Economic viability is an important issue that affects the sustainability of village electrification projects. Willingness to pay and ability to pay are assessed from this perspective.

Institutional suitability and stability: Operation and Maintenance of a power plant is a routine activity and a proper organizational structure is required to ensure reliable operation. Community involvement in this activity is very helpful. Willingness of the community to take up operational and maintenance responsibilities should be assessed during the survey. Past experience of collective action is one of the invaluable instruments to measure the co-operation among the community. Their experience in linking with Government programs is also a useful measure. From this perspective, the experience of the villagers in community action such as formation of Self Help Group, Village Development Committee is to be assessed. The presence of any NGOs in the village and their activities are to be noted so that synergy could be developed with other developmental activities being undertaken by the NGO.

Road connectivity: Type of approach road to the village has to be noticed for commutation. Operation and maintenance plays a very vital role for making the system sustainable and this could be easier with good link of roads.

Spread of the village: Unlike individual power system, the power plant has to be set up in such a place from where the distribution of electricity will require less investment and lead to good management. To find out the location of the power plant spread of the village has to be taken into consideration, i.e. whether houses are scattered or are in a cluster.

It is suggested that a village resource map could be drawn for each of the villages, which illustrate different resources available in the village such as land, available water resources, existing infrastructure, location of the houses (load centers, village spread and line diagram of possible power distribution network, proposed plant site, etc.

3.2.2.3. Technology selection. Technology selection is one of the most crucial steps to be followed in project planning stage. As the entire cost economics depends upon the type of technology to be chosen, its proper selection is essential. The main aspects that may be considered for selection of a technology are,

- Population pattern, topography of the area and quality and quantity of fuel.
- Load pattern and power delivery area.
- Local infrastructure availability.
- Capital cost, means of finance and final affordable consumer tariff structure.
- Environmental impact of the fuel and location of the plant.
- Load growth and possibility of grid interconnection in future.

The following section discusses about the step by step approaches to be followed for selection of technology.

Decision Step-1: Load to be met and power potential based on the resources are matched. All the resources that can cater to meet even the minimal load are short-listed.

Decision Step-2: If micro-hydel potential is enough to meet the entire load required, this technology is short-listed and chosen for implementation. If micro-hydel potential is not sufficient to meet the entire load demand, other potential resources can be selected and in such case hybrid power system (power plant with more than one resource) would be chosen.

Decision Step-3: If hydro resource is not found and if cattle dung–biogas resource is available, then the feasibility of this technology is studied more in detail. There are certain factors, which need to be assessed. These are:

- Cattle ownership.
- Water availability.

- Existence of migratory practice.
- Stall-feeding/open gazing of cattle.

If biogas is found suitable, it could be selected for power generation. If it is excluded, following other resources are assessed.

Decision Step-4: If the minimum estimated load is less than 1.2 kW, SPV home lighting system for individual houses is chosen. (Minimum techno-economic size of SPV power plant is 2 kWp, which can cater to 1.2 kW load considering 40% of losses in battery, inverter and distribution.) If the required load is greater than 1.2 kW and less than 5 kW, power generation through bio-oil or SVO can be checked. Power generation through bio-oil would be selected if found feasible. Otherwise solar power plant with mini grid option could be selected.

Decision Step-5: If total load is >5 kW (Minimum size of available biomass gasifier power plants is 10 kW, which can cater to load of 7–8 kW after meeting auxiliary requirements and distribution losses.), and if woody biomass potential exists, it is selected, if sustainable management of biomass resource is possible.

To ensure the availability and sustainable supply of biomass at plant site, following points have to be checked.

- Land records for availability of existing forestland and wasteland (for immediate supply of biomass as well as for energy plantation).
- Willingness of the villagers to contribute for biomass collection.
- Existence of Vana Suraksha Samiti (VSS) or Joint Forest Management Committee (JFMC) or willingness to form VSS/JFMC in the near future.
- Any possible arrangements for sustainable supply of biomass.

3.2.3. Financial framework for tariff determination

High capital cost of renewable energy systems is the foremost barrier to their large-scale dissemination. In many situations, costs amortized over the entire lifetime of the renewable energy technologies are much less than those of conventional energy options. Therefore, prior estimation of cost of electricity supply is an essential part for making judicious decision on technology selection.

In order to promote the usage of renewable based technologies, various financial and fiscal incentives are being provided by different federal and states governments across different parts of the world. In addition to the incentive provided to the incentives from government, as in the cases of other technologies, several other market based mechanism (such as energy service provider, etc.) are also being practiced around the globe.

Presently there is a huge variations are found in the literature on the cost of electricity generation from renewable resources. This is primarily due difference the input parameters used by various individuals. In the case of renewable energy the difference in the input parameters is obvious due to site-specific nature of renewable energy technologies, difference in cost, and variation in financial and fiscal incentives that are provided in a particular region. In order to get a broad overview on the cost of supply of electricity the focus was mainly given to the elements influencing the cost of supply rather than the value of parameters, which may vary from place to place.

A mathematical framework has been developed for electricity tariff estimation using “cost based method”. This method takes into account, recovery of fixed cost components such as debt repayment, interest on debt, operation and maintenance costs and also assures a fixed return on the investor’s equity. Site-specific parameters such as insolation, annual mean wind speed, sustainable biomass availability, perennial flow of water, etc. that usually influences the tariff have been incorporated in the model. Various incentives available for renewable energy technologies such as accelerated depreciation, benefit due to CO_2 reduction, etc. have also been incorporated in the model.

The cost of electricity supply is the ratio of present value of life cycle cost to the present value of electricity sales. Mathematically this can be represented as

$$\text{Cost of electricity supply} = \frac{\sum_t \text{Net cost}_t/(1+d)^t}{\sum_t \text{Electricity sales}_t/(1+d)^t} \tag{1}$$

where d is the discount rate in fraction, (discount rate takes into account time value money), t represents the time in year value of t goes up to year one to the end of life. Net cost is the net annual expenditure on electricity generation and supply in the year t. Electricity sales is the annual electricity sales in the year t.

For small DDG project electricity generation could be used as a proxy for electricity sales. The electricity generation form a renewable energy technology depends on variety of site-specific and technology specific input parameters.

3.2.3.1. Cost elements. The cost component involves, grant, loan repayment, the return of equity, the operation and maintenance cost, the fuel cost, depreciation involved. Following sections present the various elements of cost and electricity generation.

Capital cost: Capital cost is the initial cost incurred on the project it includes cost of system, wiring, civil work, commission charges, cost of land, etc. Capital cost of the renewable energy system depends on their sizes and often cost is given in per unit size of the system. Though, capital cost is the initial investment of the project, but usually operator does not pay the entire amount. There are provisions of grant, loan, tax incentive, etc.

Grant/capital subsidy: Grant or capital subsidy is a provision of money to the investors without expectations of any type of return from them. Grants are normally made so that the investor (receiving party) is able to undertake some activity it might not otherwise undertake. One the other hand, the party giving the grant is usually aiming at public good rather than private gain from the activity supported. The grants are usually made by governments (Central, State, local) and some private foundations have also provided the same. Grants can either be made in the form of a lump-sum money transfer in the initial phase of a project to share its initial cost or as a series of periodic payments to ensure the continuation of an activity (e.g. manufacture of an item) and/or reduction in the selling price.

Debt: Debt financing is the loaning of money from one party to another with the expectation that the receiving party will pay back the amount loaned along with an interest on it as per a mutually agreed upon schedule. Debt is usually available as a certain fraction of the net capital cost (after reducing the grant) Debt can be characterized in a number of ways based on one or more of the following characteristics.

Repayment period: It refers to the amount of time before full repayment of the debt is due. In case of short-term debts, the repayment is due in less than 1 year whereas the debt can be repaid in more than a year from the date of issue for long-term debts. For all renewable energy systems for DDG project long-term debt is probably more important than short-term debt.

Moratorium period: The moratorium period is the initial period during which borrowers do not repay loan. In India moratorium period up to 2 years is available on renewable energy technologies.

Interest rates: A rate is an agreement between borrower and lender, which is charged or paid for the use of money. An interest rate is often expressed as an annual percentage of the principal. For

renewable energy technologies usually there are provision of debt at lower interest rate.

Equity: Equity is the provision of money in return for partial ownership of the project. Equity financing should be explored and nurtured as one of the important options for development and dissemination of renewable energy technologies because of the following two reasons:

- The sources that provide debt are usually interested in projects with lesser risk and may not accept the risks associated with many renewable energy technologies, and
- The investments require for renewable energy systems are sufficiently large so that grants or tax credits would normally be inadequate for their large-scale dissemination.

However, the potential investors for equity financing may have other investment opportunities, offering much higher rates of return than that expected with renewable energy systems for comparable risks. Return of equity is the minimum rate of return that the equity holders are offered for bearing the risk of the DDG project and for investing in the given project.

Annual operation and maintenance cost: Operation and maintenance cost is the annual recurring cost required to carry on the functioning of the plant from day to day basis. The costs involved in the section are labour cost, maintenance cost, overhead cost, etc. Usually in the case of DDG project the operation and maintenance cost are considered as a fraction of capital cost.

Fuel cost: The cost involved in purchase or procurement of the renewable resources that will be used as fuel in the DDG projects. Fuel cost in this case is only associated with the biomass based project as the other project use those sources of fuel which comes under open access resources like wind, flow of water and solar radiation and hence no charges are associated with these as there are no owners associated with these resources.

Annual escalation in operation and maintenance and fuel cost: Escalation is the increase in the cost over the total budget per year. The operation and maintenance costs are be assumed to be increased by a certain rate.

Periodic replacement cost: In case of Solar PV and wind based project batteries need to replace by certain time period.

Accelerated depreciation: Depreciation is non-cash expense to account the reduction in the value of an asset as a result of wear and tear, age, or obsolescence. The use of depreciation affects the financial statements and primarily used for availing tax exemption on the depreciated asset. In case of renewable energy technologies accelerated depreciation benefit up to 80–100% of the system is allowed in the first in the first year. However, for availing depreciation benefit, operator should be a tax paying entity.

Renewable energy performance based incentive: This is a new kind of incentive recently being provided in some part of the world (particularly in USA). In Performance Based Incentive (PBI) payment given to the operator is based on actual energy produced in kWh by a renewable energy based system. This incentive could be availed by users irrespective of their tax status as contrast to the case of accelerated depreciation method that is applicable to only tax payee operators.

Revenue from carbon credit: Renewable energy technologies help to reduce global warming by avoiding CO_2 emission to the atmosphere. There is provision of receiving money from sale of carbon saving using renewable energy technology through CDM. It may be noted that in view of small size of DDG project it is not practically possible to directly trade carbon saving from a single project. However, options of bundling many project, programmatic CDM, or VER could be potential route to trap this opportunity.

3.2.3.2. Electricity generation. For small DDG project electricity generation could be used as a proxy for electricity sales. The electricity generation form a renewable energy technology depends on variety of site-specific and technology specific input parameters. Following sub-section presents the simple expression that could be used for estimation of annual electricity generation from a DDG project.

Annual electricity generation (EG_{PV}) in kWh from a PV based DDG system can be calculated as

$$EG_{PV} = 365 \times AF_{PV} \times P_{PV} \times I \tag{2}$$

where I: annual average daily solar radiation on PV module in kWh/m^2, P_{PV}: rated capacity of solar PV system in kWp, AF_{PV}: availability factor for PV system. The availability factor depends on the number of days of operation (n_d), efficiency of battery (η_b), matching factor of solar array (F_m), i.e. the ratio of electrical output under actual operating conditions to the electrical output if the array was operating at its maximum power point, cell temperature (T_{cell}) and temperature coefficient (β). Mathematically AF_{PV} can be expressed as:

$$AF_{PV} = \left(\frac{n_d}{365}\right) \times \eta_b \times F_m \times (1 - \beta \times (T_{cell} - 25)) \tag{3}$$

Cell temperature are usually 25 °C higher than the ambient temperature, values of other parameters can be assumed $F_m = 0.90$, $\eta_b = 0.85$, $\beta = 0.005$ per °C

Annual electricity generation (EG_w) in kWh from a small wind based DDG system can be estimated as

$$EG_w = 8760 \times AF_w \times P_w \tag{4}$$

where P_w is the rated capacity of wind system in kW, AF_w is the availability factor for wind based system can be estimated as:

$$AF_w = \left(\frac{365 - n_m}{365}\right) \times C_f \times \left[1 - \left(\frac{\rho_0 - \rho}{\rho_0}\right)\right] \times \eta_b \tag{5}$$

where n_m: number of days of shut down in a year for maintenance and others, C_f: capacity factor that takes into account both characteristic of wind turbine and wind profile of the location, ρ_0: air density at sea level (1.225 kg/m^3), ρ: air density at location, η_b: efficiency of battery.

The capacity factor (C_f) is defined as the ratio of the total electricity generated by wind energy system per year under the wind conditions at that site to the energy generated per year if the system is operating at its rated capacity all the time and can be estimated as

$$C_f = \frac{\exp\left(-(v_i/c)^k\right) - \exp\left(-(v_r/c)^k\right)}{(v_r/c)^k - (v_i/c)^k} - \exp\left[-\left(\frac{v_o}{c}\right)^k\right] \tag{6}$$

where v_i, v_r and v_o are the cut in, rated and cut off wind speeds, respectively (wind turbine characteristic) and k and c are the Weibull parameters.

Annual electricity generation (E_{GBG}) in kWh from a biomass gasifier based DDG system can be estimated as

$$EG_{BG} = 8760 \times CUF_{BG} \times P_{BG} \tag{7}$$

where P_{BG}: rated capacity of biomass gasifier in kW, CUF_{BG}: capacity utilization factor of biomass gasifier. CUF_{BG} can be estimated as

Annual electricity generation (E_{GSH}) in kWh from a micro hydro based DDG system can be estimated as

$$EG_{SH} = 8760 \times PLF_{SH} \times P_{SH} \quad (8)$$

where PLF_{SH}: plant load factor for micro hydro, P_{SH}: rated capacity of micro hydro.

3.2.4. Institutional arrangements

In order to ensure smooth functioning of the power projects, clear institutional mechanism/arrangement has to be set. It is difficult to follow a simple uniform institutional model throughout the country, particularly for a geographically culturally, socially diverse country like India. Therefore in this section, different institutional models are discussed. Depending upon the region profile and level of comfort of the stakeholder, a particular institutional model can be adopted.

In India, in the past, various models of ownership and implementation have been tried out for off-grid village electrification and other village infrastructure projects. These are:

- State Nodal Agency (SNA) owned and operated.
- SNA implemented and handed over to community organization for operation and maintenance.
- Community (users') organization owned and operated.
- Entrepreneur owned and operated.

From the experience it is clear that projects with clear ownership along with stakes built in to ensure sustainable operation have a better chance of being successful. The owner's stake element is missing in majority of the projects which have failed. Thus, it is very important to evolve an ownership and implementation model that ensures a clear ownership with stakes built for the owner to ensure sustainable operation.

The motivation of each type of owner, their stakes and relative costs are analyzed in Table 1.

3.2.5. Commissioning of the project

The installation and commissioning of the project can be done through project implementation agency that will be responsible for overall supervision of the project. The following steps could be followed for project installation and commissioning.

1. Approval of drawings and designs (it is recommended to acquire the land/project site during the DPR stage).
2. Tendering/seeking quotes from the manufacturers.
3. Processing tender bids/quotes and placement of orders.
4. Selection of equipment supplier, civil and electrical contractors.
5. Onsite training for local operators (depending upon the type of institutional models adopted).
6. Supply of power system with O&M manual.
7. Installation and commissioning of the power system.
8. Development of procedures for conducting test runs.
9. Conducting test runs of the commissioned project.
10. Development of list of spare.

3.3. Training and capacity building

Capacity building can be defined as the development of institution's or individual's core knowledge, skills and capabilities in order to build and enhance their effectiveness. Capacity building is recognised as a long-term, continuing process, in which all stakeholders participate. It is the process of assisting an individual or group to identify and address issues in order to perform a specified task effectively.

Capacity building is generally facilitated through the provision of technical support activities, training and resource networking. It is necessary to increase capacity within the service delivery chain, the financial community, the utility sector and the end-users. Capacity-building measures which could be taken up for off-grid electrification is divided into three stages (in accordance to the project stages)

- Capacity building programs during pre-installation.
- Capacity building programs during installation and commissioning.
- Capacity building programs during post-installation.

3.3.1. Capacity building during pre-installation stage

One of the reasons for failure of many RE based projects is the absence of capacity building measures at the pre-installation stage. Capacity building during the pre-installation stage is essential for making the system sustainable. The following capacity building exercises are suggested for this stage

- Awareness generation cum orientation programme for the end-users.
- Orientation programme as well as exposure visits for local officials.
- Formulation of Village Electricity Committee (VEC) and orientation of VEC on their roles and responsibilities.
- Selection of candidates among the community for getting technical training.
- Selection and formulation of Electricity Service Provider (ESP)/Franchisee.
- Selection of project sites/land for installation of the power system.

3.3.2. Training and capacity building during installation and commissioning

Besides tendering from manufacturers, placement of orders, selection of equipment supplier and civil and electrical contractors, approval of drawings and designs, the following

Table 1
Motivations of each type of owner, their stakes and relative costs.

Factors	User community owned	Entrepreneur owned	SNA owned
Motivational factors			
Work opportunity	Low	High	Medium
Political	High	Medium	High
Earnings	Low	High	Low
Energy needs fulfilment	High	Low	Medium
Mandate fulfilment			High
Stakes			
Primary losable stake (loss of)	Electricity service	Earnings	Reputation
Costs			
O&M costs (labour, management & energy resource)	Low	Medium	High
Capital servicing	Low	High	Low/medium

Table 2
Monitoring and evaluation approach for off-grid projects.

Project stage	M&E approach	
	Participatory assessment	Socio-economic impact survey
Stage I-Project planning and pre-installation preparation	Conduct preliminary participatory assessment to identify key energy needs and priorities, target communities/regions, and appropriate energy interventions Identify objectives & indicators Plan & budget for participatory assessment Design participatory assessment Conduct pilot participatory assessment Revise objectives & indicators Conduct full participatory assessment	Based on results of preliminary participatory assessment: Identify objectives & indicators Plan & budget for market survey Design and conduct pilot market survey Revise objectives & indicators Conduct full market survey
Stage II-Detailed designing & commissioning	Conduct smaller participatory assessment(s) for project monitoring	Conduct pilot baseline survey Revise objectives & indicators Conduct full baseline survey Plan follow-up surveys Conduct smaller survey(s) for project monitoring
Stage III-Post-commissioning	Analyze and document project impacts	Analyze and document project impacts
Evaluation	Conduct post-project participatory assessment Analyze and document project impacts	Conduct post-project survey Analyze and document project impacts

capacity measures could be taken up during installation and commissioning stage are:

- Development of manuals, formats for record keeping, development of procedures for conducting test runs.
- Onsite training for local operators (depending upon the type of institutional models adopted).
- Development of list of spares.
- Creating a post-installation service network.

3.3.3. Training and capacity building during post-commissioning

3.3.3.1. Billing, metering and revenue collection. Though AMC (annual maintenance contract) takes care of the technical aspect of the system it does not include the operational cost associated with the electricity delivery chain such as salary of the operator. Therefore monthly tariff has to be collected from each beneficiary.

Depending upon the type of tariff structure adopted (whether fee for services or fee for unit consumed) billing and metering (if required) should be done. Based on it and depending upon the institutional arrangement (whether SNA or VEC or entrepreneur would collect the revenue), the collection of revenue would take place.

3.3.3.2. Enterprise development. One of the ways of sustaining a rural electrification projects is to ensure that micro-enterprises develop and thrive around the project. Micro-entrepreneurs may need support to purchase the appropriate tools that will allow them to take advantage of the electricity. In addition, they may need training or other services to ensure that the utilization of electricity translates into a sustained economic benefit. In this context, training on micro-enterprise development, hand holding, etc. would take place.

3.4. Monitoring and evaluation

Monitoring and evaluation (M&E) is intended to measure the progress and success of the project with reference to agreed indicators. The indicators should be SMART (Specific, Measurable, Achievable, Realistic, Timely) so that these describes the reality and also indicate the degree of change that has resulted due to the project. Ideally, these indicators are measured at the beginning of the project, during the project, and at the end of the project, and after several years later to determine the impact of the project. Traditionally, M&E focused on assessing inputs and implementation processes. Once project implementation is underway, key indicators relating to the objectives of the project are monitored, and at the end of the project these indicators are evaluated to measure success in achieving the objectives. This usually results in misinterpretation of the observable facts and may lead to project failure.

The approach recommended here starts with the initial need assessment and continues through the project development, implementation, and evaluation. It incorporates qualitative methods to acquire in-depth insights from the consumers of energy services and more quantitative household surveys that can examine the patterns and use of energy services in the rural areas.

As described earlier, an off-grid electrification project cycle has several different stages, and the assessment and evaluation techniques applicable to each stage differ. As a result, it is difficult to specify the exact type of information that is necessary to evaluate the success or failure of the project during the early stages of the project. Participatory techniques, which allow selected households and different members within households to identify and discuss their energy problems with the researcher under the direction of a group facilitator, can reveal priority needs and the underlying causes of consumption behaviour.

In subsequent stages, quantitative information is generally necessary to allow for more standardized types of analysis and comparisons. Such information can be obtained through a survey. The specific topics to be addressed in the survey can be decided by the earlier participatory research. These quantitative approaches can be utilized in many parts of the project cycle, but require the use of different evaluation techniques that provide different kinds of data. Thus, both approaches fulfil different needs at the different stages of the project cycle. Different levels of research are required at each project stage. Table 2 illustrates the approach.

4. Conclusion

Distributed Generation offers a cost effective and valuable alternative to conventional generation of electricity for rural electrification in the country especially in the remote areas.

Technological advances have made the RE based DG technologies trustworthy and economic as compared to the conventional supply systems. The key advantage apart from the mere cost per kWh remains in the quick startup times of the DG technologies. Further, DG is not governed exclusively by economic considerations but is respectful to social upliftment, justice and democratic principles. While several pilot-scale models with local mini grids can be implemented the country to showcase the viability of RE based DG schemes; this alone would not be sufficient to mainstream it in planning process. What is needed is a meticulous planning followed by an actionable action plan based on the technical, social and economic characteristics and a determination to efficiently execute the action plan. The idea should not be only to survey the remote villages where grid electrification is economically daunting but to survey all villages and find out the least cost option for 'sustainable electrification'. There is also need to combine resource mapping and GIS based rural planning models for determining the scope and best location for implementing a project.

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